THE NICKEL BULLETIN

A MONTHLY SUMMARY OF CURRENT INFORMATION

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ABSTRACTS OF CURRENT PUBLISHED INFORMATION ON NICKEL AND ITS ALLOYS

NICKEL

Battery Plates Sintered from Carbonyl-Nickel Powder

'Sintered Nickel Plates Extend Battery Life.' *Iron Age*, 1954, vol. 174, Nov. 4, p. 150.

In long-life alkaline batteries made by the Sonotone Corporation, in U.S.A., the positive plates (produced by Amplex Division of Chrysler Corporation) are sintered from carbonyl-nickel powder. This high-purity powder is much finer than others in normal commercial supply, having a particle size of only 3–6 microns. Nickel wire screens hold the powder nickel in place.

The sintered plates are characterized by a high but controlled degree of porosity, thus ensuring a very large surface area for impregnation with the electrolyte, and resultant increased current capacity.

Nickel-cadmium batteries of this type may be operated over a relatively wide temperature range (−65° to +165°F.: −55° to +75°C.), and have the further advantage of extremely low self-discharge rate, permitting retention of the working charge for prolonged periods of idleness. The batteries are also very rugged, and require a minimum of maintenance.

Data Sheets on Nickel and Nickel Alloys

See abstract on p. 3.

Automatic Cold-Drawing of Nickel and Nickel-Alloy Tubes

See abstract on p. 3.

ELECTRODEPOSITION AND OTHER COATING METHODS

Estimation of Boric Acid in Nickel-Plating Baths

M. R. VERMA and K. C. AGRAWAL: 'Analysis of Electroplating Solutions. 2. Estimation of Boric Acid in the Presence of Nickel and Ammonium Salts.' *Electroplating and Metal Finishing*, 1954, vol. 7, Nov., pp. 403–4; Dec., pp. 458–9.

This paper is a communication from the National Physical Laboratory of India. An earlier note from the same source described a method for estimation of boric acid in nickel plating baths containing no ammonium salts or fluorides (*ibid.*, 1954, vol. 7, p. 171: *Nickel Bulletin*, 1954, vol. 27, No. 6, p. 106). Estimation of boric acid in the presence of ammonium salts presents some difficulty, in that an error is introduced by the tendency of ammonium compounds to dissociate in the region in which the titration of the mannitol-boric acid complex is completed. Methods which have been proposed for overcoming such interference are time-consuming and unsuitable for routine laboratory use, or have other limitations which are briefly reviewed by the present authors.

A procedure now proposed consists in adding, to the solution containing nickel, ammonia and boric acid an excess of formaldehyde and potassium oxalate, and titrating to a definite pH value, when any free acid already present, or that obtained from the ammonium salts, is neutralized. At this stage mannitol is added and the titration is continued, the amount of alkali consumed in the second stage being noted. The authors advance the method as being an improvement over procedures involving separation of boric acid by distillation or other means. Results of typical analyses are tabulated.

Stability Tests on Analytical Weights

See abstract on p. 18.

NON-FERROUS ALLOYS

Age-Hardenable Steels and Alloys: Reference Data

J. L. EVERHART: 'Age-Hardenable Metals.' *Materials and Methods*, 1954, vol. 40, Oct., pp. 121–36.

The principles of precipitation-hardening, and the purposes of the treatments associated with it are briefly discussed, relevant terms are explained, and the nature of the property changes accompanying such hardening is considered. This introduction is followed by sections dealing with the composition, treatment and properties of age-hardenable materials of specific types:—*light metals* (aluminium-, magnesium-, and titanium-base alloys); *heavy non-ferrous alloys* of copper, nickel, lead and precious-metal base; *irons and steels* (nitriding, stainless and tool steels); *high-temperature alloys* of nickel, cobalt or iron base, in which ageing properties are dependent on titanium, aluminium, molybdenum, carbon, used in various combinations. These sections are illustrated by tables showing properties typical of the respective materials in various conditions.

The *nickel-base alloy group* includes details of Duranickel, K and S Monels, Ni-Span C and beryllium-nickel,; the *copper group* contains alloys in which nickel is used in conjunction with beryllium and with phosphorus, and in the *high-temperature alloys* eight are of high nickel content.

Data Sheets on Nickel and Nickel Alloys

HENRY WIGGIN AND CO., LTD.
'Nickel.' *Publn.* 805, 1954; 4 pp.
'Monel.' *Publn.* 802, 1954; 4 pp.
'K Monel.' *Publn.* 803, 1954; 4 pp.
'Inconel.' *Publn.* 804, 1954; 4 pp.

These data sheets give details of composition, corrosion-resisting characteristics, physical constants, and mechanical properties of the respective materials.

Automatic Cold-Drawing of Nickel and Nickel-Alloy Tubes

'Cold Draw Goes Automatic.' *Steel*, 1954, vol. 135, Sept. 20, p. 157.

This short note describes operations in the new automatic cold-drawing section of the International Nickel Company's plant at Huntington, Virginia, in which the tubes are drawn in sets of three, and an automatic loading device eliminates loss of time between drawing of consecutive sets.

The furnace associated with this tube-drawing plant, together with the ancillary equipment (charging table, cooling chamber, discharge chamber, etc.,) is 30 ft. from end to end. The whole set-up is designed for continuous temperature-controlled annealing of nickel, Monel, and Inconel rods and tubes. It is fitted with 300 chain-driven rollers on which the work travels: those inside the furnace are made from the heat-resisting alloy Inconel, in order to obviate the need for artificial cooling. After annealing the tubes are subjected to hydraulic pressure test: the test bench used for the purpose is 85 ft. long.

It is claimed that the new cold-drawing section will triple INCO capacity for output of heat-exchanger tubes.

Isothermal Transformations in Bronze Alloys

R. HAYNES: 'Isothermal Transformations of Eutectoid Aluminium Bronzes.' *Jnl. Inst. Metals*, 1954-55, vol. 83, Nov., pp. 105-14.

The investigation described was designed to examine the reactions occurring during isothermal transformations in eutectoid aluminium bronzes of the compositions shown in the table below, and to determine the influence of nickel on the transformations.

Compositions of Alloys Studied

Cu %	Al %	Ni %	Fe %	Si %	Casting Temp. °C.
87·76	12·20	Nil	0·04	Trace	1165
86·68	12·45	0·87	Trace	Nil	1185
84·85	12·07	3·08	Trace	Nil	1230
76·09	14·88	8·40	Nil	Nil	1250

The eutectoid temperature for the β phase of the copper-aluminium system was re-determined as 565°C.±2°C., and the eutectoid composition was established as 11·96±0·05 per cent. aluminium. It is shown that the addition of nickel to this type of alloy raises the eutectoid temperature and that the eutectoid 'gutter' rises to the four-phase plane at 605°±2°C., associated with the phases α, β, γ_2 and NiAl. With increase in nickel content the gutter moves to higher aluminium contents, and it meets the edge of the four-phase plane in a triple point at about 12·7 per cent. aluminium.

A binary eutectoid alloy and similar alloys containing small amounts of nickel were transformed isothermally in the range 350°-560°C., and the results are plotted as time/temperature/transformation diagrams. Nickel has little effect on the rates of transformation, but the alloy containing 3 per cent. nickel exhibits a double knee in the curve representing the start of the eutectoid reaction. A hypothesis to explain this fact is presented.

The interlamellar spacing of the eutectoid formed at each transformation temperature was determined, and a relationship was found to exist between the interlamellar spacing of the eutectoid formed from the β phase and the degree of undercooling. When eutectoid is formed from the β_1 phase there is no such relationship, which, it is pointed out, was to be expected from theoretical considerations.

Nickel-Aluminium Bronze Propellers

'Light-Weight Copper-Nickel-Aluminium Alloy Resists Cavitation and Erosion.' *Iron Age*, 1954, vol. 174, Nov. 4, p. 152.

This brief note calls attention to the advantages of nickel-aluminium bronze (in comparison with manganese bronze) as a propeller material. A combination of lightness (some 20 per cent. saving over manganese bronze is quoted), strength, exceptional resistance to cavitation and erosion, immunity from dezincification, and improved resistance to corrosion-fatigue combine to make this type of alloy highly attractive for propeller service. Experience of the use of Nialite propellers on some American vessels is recorded.

Cobalt-Nickel-Manganese Alloys

W. KÖSTER and H. RITTNER: 'Structure and Properties of Cobalt-Nickel-Manganese Alloys.'
Zeitsch. f. Metallkunde, 1954, vol. 45, Nov., pp. 639-42.

Copper alloys containing nickel and manganese are characterized by outstanding precipitation-hardening qualities, due to the marked lessening of solubility of manganese in the ternary solid solution with fall in temperature. Reference is directed to some of the work of German investigators on that system. In view of the close similarity of constitution between the cobalt-nickel-manganese and copper-nickel-manganese systems, capacity for hardening by the NiMn phase would be anticipated in the cobalt-nickel-manganese series, and in this paper data are presented confirming this assumption. Curves illustrating the experimental results give information on hardening effects in cold-worked alloys as a function of tempering temperature, elastic modulus/temperature and modulus/composition relationships, and Curie temperatures, of alloys lying within the region susceptible to hardening.

Permanent-Magnet Materials and their Uses: Textbook

See abstract below.

Report of the Royal Mint: Nickel-containing Coinage Alloys

'Eighty-Third Annual Report of the Deputy Master and Comptroller of the Royal Mint, 1952.'
Published by Her Majesty's Stationery Office, 1954; 101 pp. Price 6/-.

This report includes details of the designs developed for the Elizabeth II coinage, returns relating to the U.K. silver, cupro-nickel, nickel-brass and bronze currency issued during 1952, currency withdrawn, medals, etc., made, and assays carried out at the Royal Mint. The reports of the activities of the Melbourne and Perth Branch Mints are also included.

In the memorandum by W. A. C. NEWMAN, Chemist and Assayer of the Royal Mint, some account is given of analytical research carried out during the year on the determination of zinc in nickel-brass coinage alloy.

NICKEL-IRON ALLOYS

Permanent-Magnet Materials and their Uses: Textbook

G. HENNIE: 'Permanent Magnets.'
Published by Franzis-Verlag, München, 1952; 132 pp. Price 23/-.

This book is designed to meet the needs of the engineer called upon to use permanent magnets in the widening range of applications in which they are now employed. In the introductory chapter the author discusses the fundamental laws of magnetism, the significance of various factors which can affect the behaviour of permanent magnets, and the meaning of the terms which are used to describe the attributes and behaviour of magnetic materials. With this background, materials used for permanent magnets are reviewed, and the individual characteristics of the respective types are discussed. The spectacular developments which have taken place during the past twenty-five years are dealt with at some length, with particular reference to the advent of alloys of nickel-aluminium- (cobalt)-iron base, which have been developed with outstanding success in many countries. Representative compositions and properties of such alloys are recorded, typical forms of magnets made from them are illustrated, and some of their major uses are indicated. Production methods are also discussed, with reference to sintered as well as cast alloy magnets. Other sections of the chapter on materials contain information on the composition, properties and uses of ductile magnet alloys of the copper-nickel-cobalt, copper-nickel-iron and cobalt-iron-vanadium types; platinum-cobalt and platinum-iron; iron powder, and oxide materials used for permanent magnets.

In the later chapters the author deals with methods of calculating and testing the properties of magnets, design of magnets, processing methods, magnetization; ageing, and external factors which may affect the operation of permanent magnets; typical uses in various industries.

Nickel-containing Permanent-Magnet Alloys: Recent Developments

'Development of New Alloys for Permanent Magnets.'
Engineering, 1954, vol. 178, Nov. 19, p. 672.

This note describes the activities of the Permanent Magnet Association, under whose auspices some of the major advances in this field have been made, e.g., introduction of Alnico alloys, and of anisotropic materials, leading to the development of Alcomax and other uni-directional magnets. More recently members of the Association have placed on the market niobium-bearing alloys of the Alcomax III and IV types, which are claimed to be two of the most efficient permanent-magnet materials now commercially available. The latest advance is the production of Columax, which is cast in such a manner that columnar crystals are developed with the same orientation as the preferred axis of magnetization. The field of application of this type of material is at present limited, but within that field it shows magnetic properties considerably superior to those of Alcomax III. Columax magnets of suitable proportions and design are characterized by an average energy value of $(BH)_{max}$ equal to 6·25 M.g.o. (mega-gauss-oersteds), and even higher values have been obtained in samples from which all crystals in an unwanted direction have been removed: a value of 8·6 M.g.o. has been reported by the National Physical Laboratory. As a comparison, the following values are quoted as typical for the Alcomax alloys:—

	$(BH)_{max}$ M.g.o.
Alcomax II (introduced 1945)	4·5
„ III (introduced 1948)	5·0
„ IV (introduced 1949)	4·5, with coercivity (Hc) of 750 oersteds

CONSTRUCTIONAL STEELS

Embrittlement of Tempered Martensite in Low-Carbon Steels

P. PAYSON: 'Effect of Carbon Content on the 500°F. Embrittlement of Tempered Martensite.'
Jnl. of Metals, 1954, vol. 6, Nov.; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 1242–3. T.N. 234E.

The phenomenon of embrittlement of tempered martensite at temperatures in the region of 500°F. (260°C.) has been studied principally in steels containing more than 0·25 per cent. of carbon. In view of the fact that very-low-carbon martensite decomposes to cementite in a manner different from that characteristic of higher-carbon martensite, experiments were made to ascertain whether the lower-carbon steels would show the embrittlement commonly

produced in the higher-carbon types when tempered in the embrittling range. The steels on which the investigation was made were of the compositions shown in the table below:—

C %	Si %	Mn %	Ni %	Cr %	Mo %
0·06	0·20	0·46	5·0	0·46	0·33
0·13	0·25	0·50	4·0	0·48	0·34
0·25	0·20	0·53	2·6	0·47	0·34

Details are given of the experimental treatments, in which specimens of the steels, after austenitizing at 1700°F. (925°C.), water-quenching, and refrigerating in liquid nitrogen, were tempered over the range 200° to 1000°F. (95° to 540°C.) at 100°F. (55°C.) intervals. Charpy tests were made on the treated specimens (and on control specimens kept in the hardened condition), at room temperature, at −100°F. (−73°C.) and at 300°F. (150°C.). The results demonstrate that the carbon content of the martensite does not change the fundamental condition responsible for the embrittlement produced by tempering within the range 500° to 700°F. (260° to 370°C.), but merely affects the transition temperature of the products resulting from such tempering. The test values obtained indicate that the lower the carbon content of the martensite, the lower is the transition temperature, and it was also observed that the higher the nickel the lower was the transition temperature.

Stabilization of the Bainite Reaction in Nickel-Alloy Steels

R. F. HEHEMANN and A. R. TROIANO: 'Stabilization of the Bainite Reaction.' *Jnl. of Metals*, 1954, vol. 6, Nov.; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 1272-80. T.P. 3896E.

The influence of partial decomposition to high-temperature bainite, on reaction kinetics at a lower temperature, was studied in two steels of the compositions shown below:—

C %	Si %	Mn %	Ni %	Cr %	Mo %	Austenite Temperature
0·38	0·28	0·74	1·79	0·81	0·26	1550°F. (840°C.)
0·31	0·30	0·76	3·07	1·22	0·49	1650°F. (900°C.)

The steels were selected as being types in which the pearlite reaction did not interfere with the bainite transformation.

The results show that reaction at the lower temperature in the bainite range may be retarded by prior partial decomposition to high-temperature bainite. The observations made are interpreted on the basis of a mechanism involving limitation in the nucleation and growth of bainite plates.

Nickel-Chromium-Molybdenum Steel Flap Tracks on the Bristol Britannia

'Britannia Flap Tracks.' *Aircraft Production*, 1954, vol. 16, Dec., pp. 478–86.

The increasing size of aircraft and the tendency of designers to specify larger, integral members are gradually changing the character of airframes and imposing new problems on production departments. Heavier and more complex machine tools of highly specialized type are required, a trend which is illustrated is the processing of flap tracks of the Bristol Britannia aircraft, the subject of this article.

The tracks are made from forgings to B.S. S.99 specification, which covers a high-carbon 2½ per cent. nickel-chromium-molybdenum steel. In the fully heat-treated condition this steel has a 0·1 per cent. proof stress of 70 tons per sq. in., and an ultimate-tensile-stress value of 80–90 tons per sq. in., with elongation of 14 per cent. for ruling sections up to 4 in. and 12 per cent. for larger ruling sections.

This article gives a detailed description of the tracks, with design drawings, and photographs illustrating the various operations carried out on these components.

Poppet Valves, Guides, and Seats: Review

See abstract on p. 12.

Determination of Tungsten in Steels

BRIT. IRON AND STEEL RESEARCH ASSOCN., METHODS OF ANALYSIS COMMITTEE: 'Improvements in the Absorptiometric Determination of Tungsten.' *Jnl. Iron and Steel Inst.*, 1954, vol. 178, Nov., pp. 267-9.

As a result of further investigation by the B.I.S.R.A. Physico-Chemical Methods of Analysis Sub-Committee, the method recommended earlier (*ibid.*, 1952, vol. 172, pp. 413–15) has been improved by modification of the solvent mixture and by an increase in the addition of titanous chloride. In order to confirm that the reproducibility of the method is not adversely affected by the changes proposed, the modified procedure was applied to a series of samples similar to those on which the original method was tested. These included a high-carbon steel, low- and high-alloy nickel-chromium steels, and other representative types. The revised procedure has been issued as a British Standard method (B.S. 1121, Part 32: 1954).

Yield Strength of Steel Weld Metals at Elevated Temperatures

See abstract on p. 13.

Flash Welding of High-Tensile Nickel-Alloy Steels

W. G. FASSNACHT: 'Flash Welding High-Strength Alloy Steels.' *Welding Jnl.*, 1954, vol. 33, Oct., pp. 937-44.

The author opens with reference to fundamental long-term investigations on flash welding of steels which are in progress at the Rensselaer Polytechnic Institute, but points out that, in the interests of expediency, some working methods have had to be developed on a rather more empirical basis by those called upon to provide welded components for industrial purposes. The information given in this paper is based on practice at the Bendix Aviation Corporation, which specializes in production of welded tubular sections of low-alloy, high-strength steel, as used in aircraft landing gear. The steels handled are heat-treated to tensile strengths of 180,000–240,000 p.s.i. (80·5–107 tons per sq. in.): they are principally types covered by S.A.E. (A.M.S.) specifications 6324, 6415 and 6427*. Following a brief review of the essential features of flash welding, the author discusses, from a practical standpoint, defects likely to occur in welding, variables of operation which must be taken into account when determining the suitable cycles (with some typical set-up charts), test methods, and post-weld treatments.

* *Typical Compositions*

	C %	Ni %	Cr %	Mo %	V %
6324	0·4	0·7	0·6	0·25	—
6415	0·4	1·8	0·8	0·25	(S.A.E. 4340)
6427	0·3	1·8	0·8	0·4	0·07

Cyclic-Temperature Tests on Dissimilar Welds in Steam Plant

See abstract on p. 15.

Wear-Resisting Products Prepared from Powders

E. GORDON, W. V. KNOPP and J. D. SHAW: 'Chromium–Nickel Alloy Steel Powders for High–Strength Parts.' *Materials and Methods*, 1954, vol. 40, Oct., pp. 107–9.

Further to studies of the production of alloy-steel compacts by sintering of pre-alloyed chromium-nickel powders with electrolytic iron powder, it has now been found possible to use a lower-cost reduced iron powder which has a low weight loss in hydrogen, and it has also been demonstrated that parts made from the iron and pre-alloyed powders are highly resistant to wear. Experiments made with compacts containing various proportions of alloyed and of iron powders, with 1 per cent. of carbon, established that economic considerations, combined with property requirements, indicate as optimum 2·5 per cent. by weight of 80–20 chromium-nickel or 7·5 per cent. by weight of 50–50 chromium-nickel powder, balance iron powder. Mechanical properties of compacts prepared by pressing and sintering of powders mixed in these proportions are tabulated in this article, and the further improvement obtainable by heat-treatment of the compacts is demonstrated by values for the tensile strength, elongation and hardness of compacts which have undergone hardening and annealing treatments.

The structure of the parts made from the iron and pre-alloyed chromium-nickel powders is illustrated, showing a fine dispersion of chromium-nickel particles surrounded by a martensitic area, in a pearlitic matrix.

It is stated that best results are obtained by pressing at 50 tons per sq. in. and sintering for one hour at 2190°F. (1200°C.). In some cases a two-hour treatment at that temperature gives higher strength, but such procedure is considered uneconomic for use in commercial practice. Dry hydrogen is the best medium, but although economically feasible for large-scale use it is relatively expensive by comparison with other atmospheres which can be employed. Dissociated ammonia and prepared endothermic gas can also be used for sintering, but treatment in such atmospheres results in lower tensile properties than when hydrogen is used. Irrespective of the nature of the gas, dryness of the atmosphere is essential. Shrinkage of parts made from powder mixtures of the types described is of the same order as for regular iron-powder parts: typical values are quoted. Addition of lubricants improves the mechanical properties of the compacts.

Although the application of the chromium-nickel steel powders is still in a very early stage, it is suggested that parts so made are likely to find increasing use in components requiring a combination of strength and wear-resistance, e.g., gears, cams, rollers.

HEAT- AND CORROSION-RESISTING MATERIALS

Properties of High-Temperature Alloys: Reference Data

W. F. SIMMONS and H. C. CROSS: 'Report on the Elevated-Temperature Properties of Selected Super-Strength Alloys.' *Amer. Soc. Testing Materials Special Technical Publn. No.* 160, 1954; 208 pp.

This report is the third in a series prepared under the auspices of the Data and Publications Panel of the A.S.T.M./A.S.M.E. Joint Committee on the Effect of Temperature on the Properties of Metals. (Earlier reports covered, respectively, a number of commercially produced stainless steels, and chromium-molybdenum steels of various types.)

The materials selected as typical 'super-strength' alloys for which data should be presented are shown in the table on p.7: the compositions given are those reported as typical, but details are also given of permissible ranges of the constituents, and of the U.S. specifications to which the materials conform.

In preparing the information, requests were sent by the Committee to all organizations in the U.S.A. known to have creep-testing facilities, and the data summarized in the report are based on replies from 19 sources, together with information already in the possession of the Committee.

The report is primarily a graphical summary of

C %	Si %	Mn %	S %	P %	Cr %	Ni %	Co %	Mo %	W %	Ti %	Nb-Ta %	Al %	V %	Cu %	N %	Fe %	
0·32	0·75	1·00	0·015	0·020	19·00	9·00		1·25	1·25	0·20	0·40					Bal.	19-9 DL
0·08	0·62	1·90			16·21	25·31		6·30							0·154		16-25-6
0·03	0·92	0·64			13·10	25·50		2·85		1·83		0·16				54·22	Discaloy 24
0·045	0·95	1·35	0·018	0·021	15·52	26·06		1·25		1·95		0·20	0·32			Bal.	A. 286
0·12	0·39	1·64	0·03		21·33	18·88	18·60	3·21	1·97		1·10				0·12		N. 155 (Low-C)
0·44	0·40	1·31			20·32	19·65	20·20	3·68	4·06		4·43					Bal.	S. 590
0·38	0·56	1·32			19·88	20·65	41·71	3·76	4·20		4·13					3·38	S. 816
0·08	0·61	1·64			20·11	10·8	Bal.		15·54							1·60	Haynes No. 25 (L. 605)
0·05	0·80	0·70			18·0	37·0	20·0	3·0		2·8		0·2				17·0	Refractaloy 26
0·08 max.	0·50 max.	0·30-1·00	0·01 max.		14·00-16·00	70·00 min.				2·25-2·75	0·70-1·20	0·40-1·00		0·20 max.		5·00-9·00	Inconel 'X'
0·10 max.	0·50 max.	0·30-1·00	0·01 max.		14·00-16·00	70·00 min.				2·00 2·60	0·70-1·20	0·90-1·50		0·20 max.		5·00-9·00	Inconel 'X' Type 550
0·16	0·70	1·08			19·0	Bal.	10·0	10·0		2·5		0·8				2·0	M. 252
0·28					27·8	2·5	Bal.	5·76								1·76	Haynes No. 21 (Vitallium)
0·48					25·1	9·69	Bal.		7·23							0·55	Haynes No. 31 (X-40)

available high-temperature data, but a brief description of the physical and mechanical characteristics of each alloy is also given, together with notes on heat-treatment, forging, and machining. The graphical data comprise curves for short-time tensile and yield strengths; elongation and reduction of area; creep rates of 0·0001 and 0·00001 per cent. per hour; rupture in 100, 1000, 10,000 and 100,000 hours, where available. An appendix contains (for some of the alloys only) some very-short-time data such as are required in design of supersonic vehicles and rocket motors. A second appendix gives as complete a list as could be compiled of known 'superalloys', with typical compositions.

The report is believed to be the most comprehensive collection of data yet published on this subject.

Data Sheets on Nimonic Alloys

HENRY WIGGIN AND CO., LTD.: 'The Nimonic Alloys. Supplementary Data on Nimonic 90 and Nimonic 95.' *Publn.* 775*, 1954; 4 pp.

The information given deals mainly with Nimonic 95, including details of heat-treatment, fatigue properties as obtained in rotating-bend tests at 870°C., short-time tensile properties at temperatures up to 1000°C., and creep characteristics at 750°, 815°, 870°, and 925°C. Fatigue-test data (at 815° and 870°C.) for Nimonic 90 are also given, supplementing information contained in earlier publications referring to that alloy.

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High-Temperature Properties of Nickel-Aluminium Alloys

W. A. MAXWELL and E. M. GRALA: 'Nickel-Aluminum Alloys for High-Temperature Use.' *Nat. Advisory Committee for Aeronautics Report*, issued Aug., 1954; abstract in *Materials and Methods*, 1954, vol. 40, Oct., pp. 179–80.

The report deals with tests made at the Lewis Flight Propulsion Laboratories, on binary nickel alloys containing 14–34 per cent. of aluminium. The composition found to yield best properties was nickel 82·5, aluminium 17·5 per cent.: typical values for room-temperature strength and creep data are given in the table below.

It is pointed out that the stress-rupture properties are intermediate between those of Inconel and Inconel 'X', but that the rates of creep are unsatisfactorily high. This limitation is considered to be due to the absence of a finely dispersed precipitate, and it is

Heat-Treatment	Addition	Tensile Strength				Extension Elongation % at Room Temperature	Total Elongation % 1500°F. (815°C.)
		Room Temperature		1500°F. (815°C.)			
		p.s.i.	t.s.i.	p.s.i.	t.s.i.		
None	None	83,800 79,600	37·5 35·5	52,900	23·5	0·6 0·6	2·9
Homogenized 16 hours at 2400°F. (1315°C.)	None	94,300	42·0	37,600	17·0	0	0·9
Homogenized 48 hours at 2000°F. (1093°C.)	None	33,400	15·0	55,300	24·5	0	2·5
Rolled 50% at 2400°F. (1315°C.)	None	86,300 82,700	38·5 37·0	50,000 51,700 21,000(*a*)	22·5 23·0	0 —	4·4 3·5 25·0
Rolled 25% at 2400°F. (1315°C.) 13% at 2200°F. (1204°C.)	None	69,600	31·0	40,400	18·0	0	1·3
	—	—	—	—	—	—	—
None	5·0% Mo	88,600	39·5	51,200	23·0	0·2	2·0
Rolled 34% at 2400°F. (1315°C.)	5·0% Mo	84,400	37·5	55,000	24·5	0·4	2·8
None	0·3% Ti	84,300	37·5	56,000	25·0	0·4	3·9
None	0·05% B	92,600	41·5	43,800	19·5	—	2·5

(*a*) Test Temperature 1800°F. (980°C.).

believed that if, by slight alloying, a precipitation-hardening phase could be introduced, the nickel-aluminium alloy could form a useful basis for a high-temperature alloy.

Impact tests, on both notched and un-notched specimens, indicate that the alloy has the characteristics of cermets, but the fact that fracture on impact was not complete would suggest that it has some inherent ductility. Under thermal-shock test it proved capable of resisting 200 cycles simulating jet-engine blow-out conditions. Oxidation-resistance of the nickel-aluminium alloy is slightly better than that of nickel-chromium alloy at 1800°F. (980°C.) and superior to that of S.816 (nickel-chromium-cobalt-base alloy) and Inconel 'X' (precipitation-hardening nickel-chromium-base alloy containing titanium, aluminium and niobium).

Either the NiAl or the Ni_3Al phase was detected in all the alloys examined: only the 82·5/17·5 per cent. alloy contained both phases. Those containing the Ni_3Al phase are hard and brittle, although showing some ductility: as-cast specimens of such alloys had room-temperature strengths of about 48,000 p.s.i. (21·5 tons per sq. in.), with 2·5–6·3 per cent. elongation. At 1500°F. (815°C.) the tensile strength was of the order of 37,000 p.s.i. (16·5 tons per sq. in.), with elongation of only 1·3 per cent. In all cases the alloys were hot-short.

A 75–25 per cent. nickel-aluminium alloy, containing only NiAl, had a room-temperature strength of 22,000 p.s.i. (10 tons per sq. in.) and showed no measurable ductility. At 1500°F. (815°C.) the strength of this alloy had risen to 31,800 p.s.i. (14·2 tons per sq. in.) with 3·8 per cent. elongation.

Although the 82·5/17·5 nickel-aluminium alloy contained both NiAl and Ni_3Al at room temperature, heat-treatment at 2400° and 2500°F. (1315° and 1370°C.) caused complete solution of Ni_3Al into the NiAl matrix. Cooling resulted in nucleation of a Widmanstätten phase at the grain boundaries, with a martensite-like phase within the grains.

High-Temperature Properties of Investment-Cast Cobalt-base Alloy

G. T. HARRIS and H. C. CHILD: 'A Statistical Study of the Creep and Fatigue Properties of a Precision-Cast High-Temperature Alloy.' *Jnl. Iron and Steel Inst.*, 1954, vol. 178, Nov., pp. 284–90.

This paper describes the properties of Jessop's G.34 alloy, which has the following nominal composition: carbon 0·8, silicon 0·5, manganese 1·0, nickel 12·0, cobalt 45·0, chromium 20·0, vanadium 2·8, molybdenum 2·0, niobium 1·2, iron 15·0, per cent. The alloy has been developed, for use in the form of precision-investment castings, from the forged cobalt-base alloy G.32.

The report is based on a statistical analysis of the mechanical properties at room temperature, creep strength over the range 700°–850°C., and fatigue strength at 700°–870°C. Quality control of the rupture strength of the alloy in the form of precision investment castings shows that this process can be used to give properties so consistent that there is no greater scatter from heat to heat than within one heat. Consideration of the creep and fatigue characteristics of the alloy leads to the conclusion that its most favourable use is at temperatures above 800°C., where it is considered that its properties rival those of some established wrought materials.

Powder Metallurgy as an Aid to Development of High-Temperature Materials

G. M. AULT and G. C. DEUTSCH: 'Applicability of Powder Metallurgy to Problems of High-Temperature Materials.' *Jnl. of Metals*, 1954, vol. 6, Nov., pp. 1214–26; disc., pp. 1227–30.

This paper presents a comprehensive survey of the contribution of powder metals and powder-metallurgy technique to the development and improvement of materials having significantly useful properties at temperatures above 1350°F. (735°C.). Since the particular interest of the authors is in materials for aircraft, possible uses of powder-metallurgy methods in production of aircraft-engine parts is given prominence in the discussion.

Sections of the review deal, respectively, with methods for production of compact materials from powders, and factors affecting their successful fabrication and properties; comparison of properties typical of wrought and of sintered alloys (as exemplified by the cobalt-base alloy X-40); sintered aluminium powder, which promises to extend considerably the maximum temperature range of the use of this metal; production and use of porous metallic components made from powders, e.g., in transpiration cooling of gas-turbine blades; molybdenum powder-produced parts; cermets of oxide, carbide, boride, silicide, and nitride base, containing binders of nickel, cobalt, nickel alloys or other metallic material. Representative cermets, hard metals and intermetallics now under investigation are listed, and the properties of typical composites are quoted.

The final section of the review is concerned with the practical application of cermets, in particular as materials for turbine blades. Results of experimental tests are referred to, and the advantages and limitations of the materials, for such applications, are critically considered. Design aspects of the use of cermets are also discussed, together with specialized methods of inspection and testing required for evaluation of their suitability for high-temperature parts operating under stress.

The survey, which is based on the literature and on original work with which the authors have been associated, is supported by a *bibliography* of over 40 references.

As a general conclusion, it is pointed out that powder-metallurgy techniques have proved to be of great value to the metallurgist interested in high-temperature engineering, in that they have provided materials which could not have been produced by other methods, and, in some cases (e.g., porous metals) in forms not otherwise attainable. Materials made by powder metallurgy are characterized by elevated-temperature strengths which compare favourably with those of comparable types made by other processes, but the

application of powder-produced components for critical parts such as turbine blading is contingent on further development, e.g., improvement of ductility and impact-resistance, and the solution of some design problems, e.g., methods of fastening of the blading.

Contributions to the discussion on this paper included a detailed report on gas analysis of titanium carbide; the properties of boride-base cermets; British work on titanium carbide-base cermets; methods of impact testing suitable for powder-metallurgy materials; tolerances to be expected in commercially produced cermet components; the importance of resistance to thermal fatigue.

Cyclic-Temperature Tests on Steam Piping

H. WEISBERG and H. M. SOLDAN: 'Cyclic Heating Test of Main Steam Piping Materials and Welds at the Sewaren Generating Station.' *Trans. Amer. Soc. Mechanical Engineers*, 1954, vol. 76, Oct., pp. 1085–9; disc., pp. 1089–91.

This paper reports tests made to determine the behaviour of welded joints between austenitic and ferritic materials which differ in thermal expansion, thermal conductivity and other physical properties. The work is a continuation of that reported by Weisberg in 1949 (*ibid.*, vol. 71, pp. 643–4). The earlier tests indicated that no failures on welded joints between the dissimilar materials tested would occur after 100 cycles representing normal operation and 10 cycles simulating boiler carry-over conditions.

After installation of the piping at the Sewaren station, a second cyclic heating test was started, on the various materials and types of weld actually used in the system. These included forged ferritic and austenitic, and cast austenitic steels; welds made between austenitic materials by various methods; welds between austenitic and ferritic materials, and an austenitic-ferritic Kelcaloy transition piece. The conditions varied from those used in the first series, in that the test section was heated by steam and was subjected to internal pressure. The form of the test sections is shown in this report and full particulars are given of the experimental conditions. The planned programme of test was as follows:—

The test comprised 100 cycles. The first five simulated rapid heating, equivalent to the maximum rate observed in operation of the piping at the station, approximately $\frac{1}{3}$ degree per second. The section was to be maintained at 1100°F. (595°C.) for one hour during each cycle and cooled rapidly at approximately 0·6 degree per second by introduction of boiler feedwater, simulating boiler-water carry-over conditions. The remaining ninety-five cycles were to represent the maximum heating and cooling rates encountered during normal start-up and shutdown periods, approximately $\frac{1}{8}$ degree per second. The test section was to be held at 1100°F. (595°C.) and 1500 p.s.i. for one hour during each cycle. An overnight 'soak' at 1000°F. (540°C.) and 1500 p.s.i. was included during alternate cycles, to simulate moderate ageing conditions. Cooling was controlled by injecting boiler feedwater into the superheated steam, and the temperature of the steam entering the test section was to be limited to a maximum of 1250°F. (675°C.). Pressure was controlled at the inlet and outlet of the test section, and the heating-steam flow was kept arbitrarily to 2,000 lb. per hour maximum. (Intended rates of heating and cooling were slightly exceeded in the tests: typical temperature cycles are graphically shown in the report.)

The results, representative examples of which are discussed, show that tests in the conditions detailed above did not produce any cracking attributable to thermal cycling. The experiments are being continued to destruction, by means of further cycling and the imposition of external bending stresses.

Influence of Nitrogen on Sigma Formation in Austenitic Steels

G. F. TISINAI, J. K. STANLEY and C. H. SAMANS: 'Effect of Nitrogen on Sigma Formation in Cr-Ni Steels at 1200°F. (650°C.).' *Jnl. of Metals*, 1954, vol. 6, Nov.; *Trans. Amer. Inst. Mining and Metallurgical Engineers*, pp. 1259–67. T.P. 3836E.

Major advances have been made during recent years in improving the corrosion-resistance of iron-chromium-nickel-base alloys, in reducing their susceptibility to sensitization and intergranular attack, and in increasing their heat-resistance. The problem of liability to formation of sigma phase, with resulting embrittlement, has not, however, been completely overcome: it is a complication in heat-resisting steels of the 25-20 and 25-12 chromium-nickel types, and there is a growing conviction that sigma phase may also be contributory to some unexpected deterioration in the corrosion-resistance of the 18-8 chromium-nickel steels.

The authors of the present paper make a short but comprehensive review of pertinent literature, and report experimental work designed to show the effect of nitrogen additions on the location of the $(\gamma+\sigma)/\gamma$ and the $(\gamma+\alpha+\sigma)/(\gamma+\alpha)$ phase boundaries in the ternary iron-chromium-nickel system, for cast and wrought alloys of simulated commercial purity, and in similar alloys containing up to about 2·5 per cent. of silicon. Twenty-four straight iron-chromium-nickel alloys were used and forty-four alloys in which varying amounts of silicon were added. The aim of the work was to define compositional limits for alloys which should be immune from susceptibility to sigma formation when exposed in the region of 1200°F. (650°C.).

The experimental methods used were as follows:—

Filings of −120 mesh size were prepared from both wrought and cast forms of the alloys and were sealed in individual Vycor tubes under partial vacuum. Except for the alloys containing silicon (which were held only 500 hours, since longer times were not necessary), the tubes, with their contents, were held at 1200°±10°F. (650°C.) for 2,000 hours and water-quenched. The X-ray diffraction powder method, using Cr Kα, was used to examine the filings. Phases were identified by direct comparison with previously prepared standard patterns of austenite, ferrite, σ, carbides, nitrides, and oxides. In many instances the filings were also examined metallographically to see if the σ phase was present.

For metallographic examination, bulk samples, approximately ⅜-in. cubes, were cut from the cast and the wrought alloys. Unstrained samples from the cast alloys were aged at 1200°F. (650°C.) for 96, 500, 2,000 and 5,000 hours and unstrained samples from the wrought alloys were aged at the same temperature for 170, 620 and 2,000 hours. Other samples from both cast and wrought alloys were strained (cold-hammered), and aged at 1200°F. (650°C.). All specimens were examined metallographically after etching with glyceregia (3 parts glycerin, 2 parts concentrated hydrochloric acid, 1 part concentrated nitric acid). This etchant attacks the sigma phase very heavily without over-etching other phases.

Samples of cast and wrought alloys which were shown to be susceptible to σ formation were nitrided and homogenized, to increase their nitrogen contents. Filings were prepared from these samples, and the samples then were aged in Vycor for 500 hours at 1200°F. (650°C.). The phases in the filings were identified by X-ray diffraction and metallography. Some bulk samples, which had also been protected by Vycor during ageing, were also examined metallographically. Later these samples were dissolved in an electrolytic ferric chloride solution and the residues were examined by X-ray diffraction.

The results on the respective alloys are shown in a series of tables, and these data are supplemented by illustrations of typical microstructures. From the observations made, the following conclusions are drawn:—

'The addition of nitrogen above amounts ordinarily found in austenitic steels of the chromium-nickel types has two effects. :—

(*a*) by precipitation of nitrides (as well as carbides), a chromium impoverishment of the matrix occurs, which gives an apparent though erroneous impression of large shifts of the σ boundaries to higher chromium contents.

(*b*) over and above the chromium-impoverishment effect, the residual nitrogen significantly displaces the $(\gamma+\sigma)/\gamma$ phase boundary at least 1 per cent. to higher chromium contents for alloys containing more than about 8 per cent. nickel; for alloys containing less than about 8 per cent. nickel the nitrogen displaces the $(\gamma+\alpha+\sigma)/(\gamma+\alpha)$ phase boundary to higher chromium contents, by an amount varying linearly from about 0 per cent. at the γ triple point to about 7 per cent. at the α triple point. These displacements are considered as the minimum displacements possible. Consideration of the small amount of iron and nickel in the nitrides as well as the small amount of nitrogen in solution would cause somewhat greater displacement of the σ-forming boundaries toward higher chromium contents.

'Even in the presence of silicon (up to about 1 per cent.) nitrogen has the ability to shift the $(\gamma+\sigma)/\gamma$ phase boundary of the iron-chromium-nickel system to higher values of chromium. In alloys containing about 1 per cent. silicon this is evident at all nickel levels, but in alloys containing about 2 per cent. silicon this ability to shift the $(\gamma+\sigma)/\gamma$ boundary exists at the 8 per cent. nickel level but has virtually disappeared at 20 per cent. nickel.

'Except in the presence of δ ferrite, σ forms at a slower rate (at 1200°F.) in the as-cast alloys than in the wrought alloys. The accelerating effect of cold work on σ formation, in both cast and wrought alloys, is clearly demonstrated.

Sigma Phase in Stainless-Steel Weld Metal

L. K. POOLE: 'Sigma Phase in Stainless-Steel Weld Metals.' *Engineer and Foundryman*, 1954, vol. 19, Oct., pp. 64–7.

Paper read before the South African Institution of Welding.

A condensed review of information on conditions causing formation of sigma phase, means for prevention, and methods of identification. The article is based mainly on published literature, supplemented by some information supplied by other investigators.

Selective Oxidation of Nickel-Chromium Alloys

J. MOREAU and J. BENARD: 'The Selective Oxidation of Nickel-Chromium Alloys at High Temperatures.' *Jnl. Inst. Metals*, 1954–55, vol. 83, Nov., pp. 87–93; disc., p. 93; *Advance Copy* 1571.

This paper comprises a full account of research briefly reported in *Comptes Rendus*, 1954, vol. 238, pp. 1659–61; see *Nickel Bulletin*, 1954, vol. 27, Nos. 7–8, p. 145.

The mechanism of selective oxidation of a nickel–4·6 per cent. chromium alloy was studied between 800° and 1250°C., using mixtures of hydrogen and water vapour as oxidizing agent.

The morphology of the oxide formed on the surface of the alloy differs markedly from the surface structure of the unoxidized metal. Nucleation of Cr_2O_3 is followed by its coalescence; at a later stage the primary oxide evaporates and the bare metal takes on a striated appearance.

Various aspects of the observations are discussed, in particular the surface striations. In an oxidizing atmosphere, the surface of the specimen may be considered not as a free-metal/atmosphere boundary, but as a metal/oxide interface. Selective oxidation of the chromium contributes to the building-up of this surface oxide film; when the temperature is sufficiently high, the lattice of the metal beneath undergoes a reorganization, as a result of which the metal surface is enabled to adopt the micro-profile corresponding to its state of minimum free energy.

Calculation of Small Elements for Domestic Electrical Equipment

H. HODGES: 'Calculating Small Elements.' *Henry Wiggin and Co., Ltd. Publn.* 773*, 1954; 4 pp.

This publication is intended to assist those engaged in construction, re-winding, or repair of small domestic electrical-heating elements, as used for fires, space heaters, cooking equipment and other small appliances.

Materials are first considered. These are mostly of the nickel-chromium or nickel-chromium-iron alloy

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types, and their characteristics are discussed with specific reference to the properties of Brightray C, a typical nickel-chromium alloy made by the most modern metallurgical techniques. Tables show the physical properties of this material and the resistance of various gauges, in sizes most likely to be used for small elements.

Factors affecting calculation of length and size of wire, permissible watts density, wire temperature, diameter of mandrel, winding of spiral and other variables are discussed, with typical examples. Finally, recommendations are made with regard to joining of the conducting lead and the heating element, and the importance of sound end connexions is emphasized.

Titanium Carbide/Nickel Cermets

A. E. JOHNSON: 'Mechanical Properties at Room Temperature of Four Cermets of Titanium Carbide with Nickel Binders.' *Nat. Advisory Committee for Aeronautics, Tech. Note* 3197, *Aug.*, 1954; 22 pp.

Abs. in *Materials and Methods*, 1954, vol. 40, Oct., p. 182.

The following room-temperature properties are reported by Langley Aeronautical Laboratory, U.S.A., for titanium carbide-base cermets containing various amounts of nickel as binder.

Composition TiC/Ni	Tensile Strength		Compressive Strength		Shear Strength		Hardness Rockwell 30-N	Density lb./cu. in.	Compressive Yield Stress	
	p.s.i.	t.s.i.	p.s.i.	t.s.i.	p.s.i.	t.s.i.			p.s.i.	t.s.i.
95- 5	38,000 37,500	17·0 16·7	330,000 327,000	147·5 146·0	36,000 (*a*)	16·1	88	0·171	—	—
90-10	65,500 72,000	29·25 32·10	353,000 349,000	157·60 155·8	56,000 74,000	25·0 33·0	88	0·178	—	—
80-20	74,000 77,500	33·1 34·6	350,000 351,000	156·2 156·6	89,000 95,000	39·7 42·4	84	0·190	286,000 289,000	127·6 129·0
70-30	115,000 118,000	51·3 52·6	337,000 335,000	150·4 149·6	101,000 99,000	45·1 44·2	79	0·200	238,000 235,000	106·2 105·0

(*a*) No test.

Poppet Valves, Guides, and Seats: Review

'Poppet Valves, Guides, and Seats.

I. A Survey of Valve Materials and General Design Features.

II. Valve Guides, Seat Inserts and Other Considerations.'

Automobile Engineer, 1954, vol. 44, Sept., pp. 349–56; Oct., pp. 421–8.

The review opens with a consideration of the operating conditions to which valves are subject, drawing attention to the complications which have arisen during recent years as a result of introduction of the higher speeds, larger compression ratios and increased ratings of modern engines. From a consideration of the conditions now obtaining, it is concluded that the following properties are desirable in valve materials:—resistance to scaling (or formation of an adherent scale); resistance to corrosion, at both normal and elevated temperatures; good strength and hardness at operating temperatures; high impact strength at service temperatures; good wear-resistance (in stems and seating faces); high thermal conductivity at working temperatures; low coefficient of expansion; resistance to thermal and mechanical fatigue, and to creep; good forgeability and machinability; good response to heat-treatment; low cost.

In the light of the above requirements, British valve materials currently in use are reviewed. Two comprehensive tables show:—(1) composition of materials, and the specifications to which they conform, heat-treatments used for the various types, valves for which they are used, thermal coefficient of expansion (20°–600°C.), and the relative advantages and limitations of the respective materials; (2) mechanical properties, impact-resistance, and hardness, at room temperature and at temperatures in the range 600°–800°C. For some of the materials creep data are also recorded. Both the high-alloy nickel-containing austenitic steels employed for exhaust valves and the lower-alloy grades suitable for inlet valves are represented in the survey, as well as the nickel-chromium alloys used for valves and as valve-coating materials.

The next section describes the various methods used for production of valves, with some notes on the relative advantages of each process, for specific applications. General considerations governing the form of valves are considered, and design is discussed in relation to valves used in engines of standard types.

Part II of the review is concerned with valve guides (materials, design and operation), and with seat inserts, of which typical forms are illustrated. Problems arising in operation are considered, with special reference to seat distortion, and methods of avoiding this trouble are recommended.

Failures liable to occur in valve components are considered in five groups: sticking, burning, breakage, scuffing or wear, and corrosion. Although no general rules can be laid down to ensure freedom from failures of any of these types, some general guidance is given, and failures arising from various causes are discussed and illustrated.

In connexion with reduction of the operating temperatures of valves, reference is made to sodium

cooling, and the advantages of sodium for this purpose are indicated. Finally, attention is directed to various forms of rotating valve which have been introduced in U.S.A., Germany and England. Such valves, although not successful in all applications, have solved certain problems: sticking and gumming are reduced and seating is improved, blow-by is practically eliminated, and valve-head temperature is reduced.

The above survey is supported by reference to nearly 40 *items of literature*.

Yield Strength of Steel Weld Metals at Elevated Temperatures

T. NOREN and B. RAMSHAGE: 'Yield Strength of Weld Metals at Elevated Temperature.' *Svetsaren*, 1953, No. 4; abstracted by G. E. CLAUSSEN, in *Welding Jnl.*, 1954, vol. 33, Oct., Suppl., p. 544S.

Values are given in the table below for all-weld-metal specimens. The first ten were deposited by covered corrosion- and heat-resisting steel electrodes: the last one by a high-tensile low-hydrogen electrode. The electrode was used on reverse polarity, and deposited 0·31 and 0·34 lb./1000 amp./min., respectively, of core rod and weld metal.

Composition of Weld Metal					Yield Strength, at temperatures shown, p.s.i. (t.s.i.)					
C %	Cr %	Ni %	Mo %	Nb %	20°C.	100°C.	200°C.	300°C.	350°C.	400°C.
0·07	18	9	—	—	54,000 (24·0)	48,000 (21·5)	44,000 (19·5)	43,000 (19·0)	41,000 (18·5)	41,000 (18·5)
0·07	18	9	—	1	66,000 (29·5)	61,000 (27·0)	57,000 (25·5)	55,000 (24·5)	54,000 (24·0)	53,000 (23·5)
0·07	19	8·5	1·5	—	64,000 (28·5)	57,000 (25·5)	51,000 (23·0)	51,000 (23·0)	51,000 (23·0)	48,000 (21·5)
0·07	18	9	1·5	—	58,000 (26·0)	50,000 (22·5)	47,000 (21·0)	46,000 (20·5)	44,000 (19·5)	41,000 (18·5)
0·20	25	—	—	—	54,000 (24·0)	50,000 (22·5)	47,000 (21·0)	50,000 (22·5)	51,000 (23·0)	46,000 (20·5)
0·17	24	5	—	—	74,000 (33·0)	66,000 (29·5)	60,000 (27·0)	56,000 (25·0)	56,000 (25·0)	54,000 (24·0)
0·07	19	8·5	2·5	—	68,000 (30·5)	63,000 (28·0)	57,000 (25·5)	53,000 (23·5)	51,000 (23·0)	51,000 (23·0)
0·07	18	9	2·5	—	73,000 (32·5)	66,000 (29·5)	60,000 (27·0)	56,000 (25·0)	54,000 (24·0)	53,000 (23·5)
0·13	26	21	—	—	48,000 (21·5)	44,000 (19·5)	40,000 (18·0)	37,000 (16·5)	36,000 (16·0)	36,000 (16·0)
0·20	24	5	1·5	—	76,000 (34·0)	68,000 (30·5)	63,000 (28·0)	57,000 (25·5)	56,000 (25·0)	53,000 (23·5)
C %	Si %	Mn %	Mo %							
0·10	0·50	1·50	0·40-0·50	As-welded	83,000 (37·0)	80,000 (35·5)	76,000 (34·0)	74,000 (33·0)	70,000 (31·0)	67,000 (30·0)
0·10	0·50	1·50	0·40-0·50	Stress-relieved	77,000 (34·5)	74,000 (33·0)	71,000 (31·5)	68,000 (30·5)	66,000 (29·5)	64,000 (28·5)
0·10	0·50	1·50	0·40-0·50	Normalized	54,000 (24·0)	52,000 (23·0)	50,000 (22·5)	48,000 (21·5)	47,000 (21·0)	45,000 (20·0)

Elevated-Temperature Properties of Chromium-Nickel Steel Welds

R. D. WYLIE, C. L. COREY and W. E. LEYDA: 'Stress-Rupture Properties of Some Chromium-Nickel Stainless-Steel Weld Deposits.' *Trans. Amer. Soc. Mechanical Engineers*, 1954, vol. 76, Oct., pp. 1093–1104; disc., pp. 1104–6.

The continuous rise in temperature and pressure conditions in central-station power-boiler equipment has reached a stage at which boilers now in operation deliver superheated steam to the turbine at 1050°F. (565°C.) and 2300 p.s.i. pressure; installations under construction will operate with 1100°F. (595°C.) steam temperature, and, as tube materials of higher strength become available, units delivering steam at 1200°F. (650°C.) may be envisaged. With such increase in outlet steam temperature it has become necessary to use high-strength austenitic tubing for

the outlet ends of superheaters: metal temperatures of these parts are now in the range 1200°–1250°F. (650°–675°C.) and in the 1100°– 1150°F. (595°–620°C.) steam units superheater-metal temperatures of 1300°–1400°F. (705°–760°C.) may be expected.

In anticipation of these progressively severer conditions, many tests have been made to provide information relevant to design, and the American Society of Mechanical Engineers has already collected sufficient data for establishment of design stresses for most of the wrought austenitic steels which will be required in the service conditions anticipated.

Since the materials under consideration are used in tubular form, and, in the construction of superheaters, are joined together by welding, the Babcock and Wilcox Company undertook, in 1949, a comprehensive programme of tests to determine the high-temperature strength of stainless-steel weld deposits as currently produced and used. This paper reports the results.

The compositions of the weld metals investigated are shown in the following table:—

Most of the electrodes used were of commercial quality.

The tests were made on all-weld-metal produced by depositing multi-layer pads on a base plate. Two types of stress-rupture specimen were used: one provided for the direction of applied stress being normal to the direction of weld-bead deposition (representing the direction of the major stress axis in a longitudinal weld seam in a drum or header, or in a seal weld): the other was designed so that the direction of applied stress would be parallel to the direction of weld-bead deposition (representing the direction of major stress in a circumferential tube or pipe weld). Both specimens are illustrated, and details are given of the test procedure.

The tests were made at several temperatures (1000°–1500°F.: 540°–815°C.), selected with reference to the service conditions to which the respective weld materials are likely to be subjected: the majority were made at 1200°F. (650°C.). In many cases duration of test was more than 10,000 hours. From the data obtained, values were selected for the stresses to

Table I
Chemical Analyses of Deposited Weld Metal

Material	C %	Mn %	Si %	Cr %	Ni %	Mo %	W %	Nb %	Ta %
19 Cr—9 Ni	0·07	1·62	0·51	19·36	9·63	—	—	—	—
	0·09	2·23	0·49	18·74	9·06	—	—	—	—
19 Cr—9 Ni .. .. (low-C)	0·03	1·02	0·16	19·77	10·57	—	—	—	—
19 Cr—9 Ni .. .. (Nb-stabilized)	0·09	1·62	0·53	19·96	9·78	—	—	1·06	—
	0·08	1·52	0·46	19·47	10·06	—	—	1·43	—
	0·07	1·81	0·52	19·88	9·90	0·10	—	0·91	—
19 Cr—9 Ni .. (Nb+Ta-stabilized)	0·09	2·20	1·06	18·59	8·86	—	—	0·68	0·17
19 Cr—9 Ni .. (DW)	0·29	1·61	0·94	20·79	7·98	1·21	1·49	0·62	—
18 Cr—12 Ni—3 Mo ..	0·14	1·60	0·40	19·65	13·58	3·22	—	—	—
	0·10	1·94	0·59	18·68	13·82	2·09	—	—	—
18 Cr—12 Ni—3 Mo .. (low-C)	0·03	1·08	0·19	18·62	13·28	1·70	—	—	—
18 Cr—12 Ni—3 Mo .. (Nb-stabilized)	0·07	1·97	0·50	19·10	12·21	2·25	—	0·74	—
25 Cr—20 Ni	0·22	2·10	0·45	25·23	21·14	—	—	—	—
	0·18	2·65	0·33	24·78	18·92	—	—	—	—
	0·12	1·48	0·42	25·92	22·12	—	—	—	—
25 Cr—20 Ni .. (Nb-stabilized)	0·11	1·97	0·65	25·39	18·16	—	—	1·15	—
	0·13	1·84	0·65	25·36	20·25	—	—	1·20	—

produce rupture in 100, 1000, and 10,000 hours: these are given in the original. The fractured specimens were metallographically examined after test, and this examination was supplemented by determination of magnetic permeability and of Vickers hardness, on a selection of representative specimens. The report is amply illustrated by photomicrographs indicating the effects of prolonged exposure to elevated temperatures under stress.

From the values obtained for the various types of material it is concluded that welds show, in general, rupture strengths lower than those of wrought materials of corresponding compositions: this is particularly noticeable at temperatures above 1200°F. (650°C.). The properties of niobium-stabilized deposits were superior to those of unstabilized welds of otherwise similar composition. It is indicated that further work is required to develop electrodes capable of depositing weld metal entirely satisfactory for service at temperatures above 650°C. Austenitic weld deposits have inherently low rupture ductility, as compared with the corresponding wrought materials, but it is believed that there may be some possibility of improving this property, particularly for short-term service, by modification of chemical composition and structural characteristics.

With regard to the physical and structural changes occurring in the weld metals investigated, the following conclusions are drawn:—

Magnetic-permeability measurements indicate that the higher the test temperature (for the test periods employed in this investigation), the more complete is the transformation of delta ferrite to a non-magnetic phase, either sigma or austenite.

Weld deposits stabilized with niobium were found to form sigma phase more rapidly and more completely from delta ferrite than did unstabilized deposits. This transformation was confirmed by the high hardness of the niobium-containing specimens, in comparison with that of unstabilized or extra-low-carbon types. Unstabilized weld deposits of extra-low-carbon content showed no tendency to age-hardening within the conditions used, and they had a lower hardness than steels of normal carbon content.

Stabilized deposits exhibited higher hardness than unstabilized types, in both the as-welded condition and after high-temperature test, which is believed to be the result of strengthening of the solid-solution matrix as well as of the mode of precipitation of sigma phase and carbide.

It was observed that high hardness at room temperature is not always associated with good stress-rupture properties: 25-20 chromium-nickel steel is quoted as confirming this conclusion.

Further work is in progress in the Babcock and Wilcox laboratories, to evaluate more closely the high-temperature strength of austenitic welded joints, and their room-temperature mechanical properties after prolonged exposure at elevated temperatures.

In discussion, W. L. FLEISCHMANN presented data obtained at the Knolls Atomic Power Laboratory, on Type 347 weld metal (carbon 0·08 max., chromium 17-19, nickel 9-12 per cent., niobium 10×C min.). R. D. THOMAS gave results of relatively short-time high-temperature tests (made by Arcos Corporation in co-operation with The International Nickel Company) on four types of weld metal comparable with some of the specimens examined by the author, viz., niobium- and niobium-tantalum-stabilized 19-9 chromium- nickel, 18-12 containing molybdenum, and niobium-stabilized 19-12 containing molybdenum.

Resistance Welding of Stainless-Steel Bellows

T. A. DICKINSON: 'The Use of Resistance Welding in the Manufacture of Stainless-Steel Bellows.' *Sheet Metal Industries*, 1954, vol. 31, Oct., pp. 854-5.

This short article describes developments at the plant of Circle Weld Company, Burbank, California, where stainless-steel bellows are being produced to meet the following requirements:—

(*a*) The bellows must be made from sheet ranging from 0·002 to 0·016 in. in thickness.

(*b*) Tubes made from the sheet must have welded joints of quality such that they will remain leak-proof under severe forming operations.

(*c*) In certain areas of the bellows parts of varying thickness have to be assembled.

Details of the resistance-welding equipment which has been devised to secure suitable welds in these conditions have not yet been made public, but it is known that it comprises single-phase A.C. machines with ratings of 10, 20, 45 and 65 kVA.

The initial step in fabricating the bellows consists in manually wrapping a thin stainless-steel sheet round a wooden mandrel, grooved so as to support a copper bar at the point at which a tubing seam is to be welded. Length and diameter of the mandrel are regulated according to the tube being made. Strips of masking tape hold the edges of the steel sheet together in correct alignment with the copper bar of the mandrel, and the ends of the copper bar are subsequently attached to a pair of A.C. terminals, to serve as the lower resistance-welding electrode. As the tube is welded the strips of tape are progressively removed.

'Fins', which permit use of the tubes as bellows, are hydraulically formed on the welded components in much the same way as if the bellows were being made from seamless tubing, and valves, fittings and other attachments are then spot- and seam-welded as necessary to the ends of the bellows.

Cyclic-Temperature Tests on Dissimilar Welds in Steam Plant

G. F. LIEN, F. EBERLE and R. D. WYLIE: 'Results of Service Test Program on Transition Welds between Austenitic and Ferritic Steels at the Philip Sporn and Twin Branch Plants.' *Trans. Amer. Soc. Mechanical Engineers*, 1954, vol. 76, Oct., pp. 1075-83; disc., p. 1083.

This paper reports tests carried out by the American Gas and Electric Company, in plants operating under two of the large electric supply companies of the U.S.A. The parts joined were headers made from a

steel containing chromium 2¼, molybdenum 1 per cent. and stop valves of niobium-stabilized chromium-nickel steel. The piping arrangement involved is shown in the paper.

Welding of the two parts called for a joint which would withstand operation at 2,000 p.s.i. and 1050°F. (565°C.), in addition to stresses resulting from the wide difference in coefficients of expansion between the two materials. Flanged joints, cast transition joints, and other types were considered, and conventional butt welding was eventually selected. The weld-test vessel in which the joints were embodied is illustrated, and cycling procedures are detailed. The dissimilar welds, in all three installations used for the test, were inspected periodically by the fluorescent-penetrant method and by radiographic examination: metallographic examination of some of the specimens was also made in connexion with certain defects observed by the other two procedures.

The results demonstrate that ferritic-austenitic joints subjected to thermal cycles between about 980°-1010°F. (525°-545°C.) and 300°F. (150°C.) may develop not only oxide notches or cracks at the surface, but also cracks below the surface. Both types appear to occur only in the less oxidation-resistant and weaker low-alloy steel, in a region directly adjacent to the dissimilar-metal weld-fusion interface. The notches or cracks occurring at the surface are considered to be of the stress-oxidation type, whereas those below the surface originate in the absence of oxygen. It is believed that the stresses set up by differential expansion are primarily responsible for the occurrence of the latter type.

Propagation of cracks under operating conditions at two of the plants was slow, and would indicate that dissimilar welds in main steam lines which are subjected to much less frequent thermal cycles than those used in the test vessels will give many years of satisfactory service. Some observations are made as to the relative validity of the test methods used and the extent of the information to be gained from them.

Welding of Precipitation-Hardenable Stainless Steels

C. W. FUNK and M. J. GRANGER: 'Metallurgical Aspects of Welding Precipitation-Hardening Stainless Steels.' *Welding Jnl.*, 1954, vol. 33, Oct., Suppl., pp. 496S-508S.

The design and fabrication of airborne components calls for the use of materials having high strength-to-weight ratios, and the same principle holds for construction of liquid-propellant rocket power plant, with the additional need for ductility, serviceability at high temperatures, and ability to resist attack by corrosive environments. Fabrication considerations impose further limitations, e.g., availability in sheet form, weldability, and good workability. In the light of these combined requirements, comparison has been made of various materials which, on the basis of individual properties, might be considered for such applications. A chart in this paper shows yield strength/weight ratios for the following aircraft materials, at 75°, 300° and 700°F. (24°, 150°, and 370°C.):—light alloys (magnesium- and aluminium-base), titanium, annealed niobium-stabilized and annealed straight 18-8 chromium-nickel steels, and precipitation-hardening 17-7 chromium-nickel steel containing 0·75-1·5 per cent. of aluminium. The comparisons show that at 300°F. (150°C.) the precipitation-hardening steel assumes a dominant position, and that at 700°F. (370°C.) it has a four-fold advantage, on the yield strength/weight basis, over its nearest competitor, titanium.

Steels typical of precipitation-hardening grades are Stainless W, 17-4 PH, 17-7 PH and V 2B, the compositions of which are shown in the table below.

The effect of alloy content on the properties of such steels is discussed, showing that composition must be so balanced, and/or heat-treatment must be such, that a transformation of face-centred cubic structure (characteristic of the austenitic matrix) to body-centred cubic occurs during cooling from the solution-treatment temperatures, simultaneously retaining the

Compositions of Precipitation-Hardening Stainless Steels

	C %	Si %	Mn %	S %	P %	Ni %	Cr %	Ti %	Al %	Mo %	Be %	Cu %	Nb-Ta %
Stainless W ..	0·06	0·58	0·54	0·016	0·016	7·28	17·60	0·90	0·17	—	—	—	—
17-4 PH.. ..	0·07 max.	1·00 max.	1·00 max.	0·03 max.	0·04 max.	3·00–5·00	15·50–17·50	—	—	—	—	3·00–4·00	0·25–0·45
17-7 PH.. ..	0·09 max.	1·00 max.	1·00 max.	0·03 max.	0·04 max.	6·50–7·75	16–18·00	—	0·75–1·50	—	—	—	—
V 2 B	<0·07	2·25–3·25	0·50–0·75	—	—	9·75–10·25	19–19·5	—	—	3·0–3·5	0·10–0·20	—	—

hardening element in solid solution. The hardener may be any of several elements, but must be soluble in austenite and insoluble in ferrite. Reheating of the material at a temperature below that required for the ferrite-to-austenite transformation permits precipitation of the hardening phase. It is assumed that in 17-7 PH the precipitate is an Al-Ni compound, in 17-4 PH a dispersed copper-rich phase, and in V 2B a complex beryllide. Balancing of composition to secure optimum hardening and properties is considered by the author, with particular reference to 17-7 PH. The austenitic balance and initial transformation temperature are especially sensitive to the carbon and aluminium contents.

Standard heat-treatment equipment may be used for the precipitation-hardening stainless steels: hydrogen or cracked-ammonia atmospheres give best protection, and salt-bath heat-treatment is satisfactory in most cases. Protective gas atmospheres containing carbon monoxide or carbon dioxide must be used with caution, since the stainless steels readily absorb carbon at elevated temperatures, resulting in stabilization of austenite and impaired response to precipitation heat-treatment. Stress-relief annealing is required between forming operations; annealing for homogenization is necessary prior to temper-hardening, and post-weld annealing must be used to remove areas of heterogeneous structure from welded joints. Temperatures suitable for annealing are shown in this paper, together with properties typical of the respective materials in the annealed conditions.

For the 17-7 PH type of steel an intermediate transformation heat-treatment is necessary after solution treatment, since in this composition the annealed, solution-treated steel is essentially austenite: the other materials considered in this paper are principally ferritic as annealed. The transformation cycle usually requires heating for about 1½ hours at 1400°F. (760°C.): the possible range of treatment is 1100°-1700°F. (595°-925°C.), and holding time within this range may vary from half to three hours, depending on the temperature selected. Cooling should be as rapid as possible, and the material should then be held for at least 30 minutes at 60°F. (15°C.). Properties typical of 17-7 PH in the transformed condition are tabulated.

Age-hardening is produced by heating within the range 900°-1100°F. (480°-595°C.); times vary from one to eight hours. V 2 B requires the longest treatment, eight hours at 950°F. (510°C.); the other types considered may be aged for half to one-and-a-half hours. In the aged condition all the steels show very high strengths, with correspondingly low elongations. At the plant with which the authors are associated (Aerojet-General Corporation) an ageing temperature of 1100°F. (595°C.) has been standardized, as giving better ductility, though somewhat lower strength, than that resulting from treatment at 1050°F. (565°C.), and therefore being more suitable for use in welded structures.

Each of the precipitation-hardening stainless steels discussed in this paper is reported to be weldable, but the authors' experience has been confined to 17-7 PH, in sheet form, and the information given on welding is therefore limited to this material. Such steel can be satisfactorily welded by any of the arc and resistance techniques, if oxidation and loss of aluminium are avoided. Although pre-heating has not been found necessary, post-weld annealing has been used to improve ductility of the joints. With the inert-gas tungsten-arc process helium or argon may be employed to prevent oxidation of the aluminium and formation of slag. Use of 17-7 PH filler wire necessitates the use of the inert-gas shielded arc process, because loss of alumina cannot be prevented by electrode coatings. Addition of aluminium to the flux adversely affects the chemical balance of the weld. Metallic-arc welding with 17-7 PH filler may be used if the bead is sufficiently diluted with the parent metal, which provides for response to the double heat-treatment required to obtain optimum properties in this material.

Study of porosity liable to occur in 17-7 PH welds has shown that the type found in automatically prepared welds is distinctive, being characterised by the occurrence of voids in a linear pattern along the edge of the fusion zone. Gas liberated from the parent metal is believed to be the cause of this type of porosity, which is capable of causing serious loss of elongation. The use of a relatively high ageing temperature (1100°F.: 595°C.) improves the elongation for any given degree of porosity. Moisture in the argon shielding gas may also cause porosity: even a small amount can be significant, but substitution of helium for argon, in automatically prepared welds, practically eliminates porosity. A further cause of porosity is accelerated speed of welding or rapid solidification of the crater.

Comparison of helium-shielded with argon-shielded tungsten-arc welds has shown that, at any given hardness level, the former give almost double the elongation of the latter, with equal or superior mechanical strength.

Abnormal hardness, found at each stage of heat-treatment, in the heat-affected zones of the 17-7 PH welds, is believed to be the effect of heat-input during welding. Although this effect was not apparent in the microstructure, variation in the reflectivity of the microsurface was observed. Hardness traverses showed a soft and a hard zone, presumably due to the thermal gradient during welding. This abnormality was eliminated by annealing for 40 minutes at 1900°F. (1035°C.).

Notch-sensitivity tests reported in this paper indicate that small discontinuities attributable to slag or non-fusion are more significant than mechanically introduced discontinuities.

Cleaning of Stainless Steel for Wire Drawing

J. H. CORSON: 'Cleaning of Stainless Steel for Wire Drawing.' *Wire and Wire Products*, 1954, vol. 29, Oct., pp. 1143–4, 1146–7.

The author first considers the nature of the scale formed on stainless steel during annealing, and then critically discusses the various methods which are in use for de-scaling.

Conditions present in batch-type annealing (which is the method most generally used for bars, rods, and

coarse and medium wire) result in formation of a heavy oxide. Other problems may arise through the presence, on the surface of the wire, of traces of the soap or grease used as lubricant.

In order to assist in devising treatments most suitable for the respective types of stainless-steel wire, a study has recently been made of the composition of the oxides formed on several common grades of steel during annealing. Details are given in this paper of the approximate composition of the films formed, by heating at 900°C., on a typical 12 per cent. chromium steel, a straight 18-8 chromium-nickel type and a steel of Type 316 (chromium 18-20, nickel 11-15, molybdenum 3-4 per cent.). The data show that chromium and silicon tend to concentrate in the scale, but that the iron, nickel and molybdenum contents of the scale are lower than those of the respective parent steels.

The author also emphasizes the importance of a knowledge of the physical character of the scale formed. To demonstrate this, photomicrographs are shown illustrating the layered structure of scale formed on three types of straight-chromium steel heated at various temperatures.

Enquiries made among representative U.S. producers of stainless-steel wire lead to the conclusion that cleaning practices vary widely. Information based on this enquiry is summarized in Tables I and II below, which give the practices standard in some large wire-drawing plants.

The E.I. du Pont de Nemours Company, who sponsor the sodium hydride bath, claim that the scale is actually reduced by the use of this salt; the Hooker Company, proprietors of Virgo salts, state that this bath 'conditions' the scale, and makes it more easily removable. The relative advantages of the two types, and the exact composition and conditions of use of the molten salt and acid baths, are critically discussed by the author.

Table I

Industry Cleaning Practices

Bar and Coarse-Wire Manufacturers

Austenitic Steels

1. Sodium Hydride
   Water Quench
   Sulphuric Acid
   Water Wash
   Nitric-Hydrofluoric Acids
   Water Wash

2. Sodium Hydride
   Water Quench
   Sulphuric Acid
   Water Wash
   Nitric-Hydrofluoric Acids
   Water Wash

3. Virgo Salts
   Water Quench
   Muriatic Acid
   Water Wash
   Nitric-Hydrofluoric Acids
   Water Wash

4. Virgo Salts
   Water Quench
   Sulphuric Acid
   Water Wash
   Nitric-Hydrofluoric Acids
   Water Wash

5. Caustic
   Water Quench
   Sulphuric Acid
   Water Wash
   Nitric-Hydrofluoric Acids
   Water Wash
   Permanganate
   Water Wash
   Sulphuric Acid
   Water Wash

Chromium Stainless Steels

The procedure is the same except that nitric acid is used instead of nitric-hydrofluoric acid.

Table II

Industry Cleaning Practices

Fine-Wire Manufacturers

1. Virgo Salts
   Water Quench
   Krupp Solution*
   Water Wash
   Nitric Acid
   Water Wash

2. Sulphuric Acid
   Water Wash
   Nitric-Hydrochloric Acids
   Water Wash

3. Sodium Hydride
   Water Quench
   Nitric-Hydrochloric Acids
   Water Wash

* Aqueous solution contains— Sulphuric acid 15, nitric acid 2½, hydrofluoric acid 2½, per cent.

Stability Tests on Analytical Weights

P. H. BIGG and F. H. BURCH: 'Further Tests on the Stability of Analytical Weights in Chemical Laboratories.' *Brit. Jnl. Applied Physics*, 1954, vol. 5, Nov., pp. 382-6.

In experiments reported in 1950 analytical weights of various materials were subjected to accelerated corrosion and stability tests in representative chemical laboratories. The results showed that as regards stability of mass there was little to choose between weights of 25-20 chromium-nickel steel, non-magnetic nickel-chromium alloy (80-20 type), and chromium-, rhodium- and platinum-plated weights having a nominal thickness of plating of about 15 μ (0·0006 in.) or more. Some weights of specially highly polished 25-20 steel showed particularly satisfactory behaviour.

In view of the claims recently made for the corrosion-resisting properties of 65-35 tin-nickel alloy electrodeposited coatings, tests have been carried out on 100-gram brass weights, of normal forms, plated with this type of coating. Three variants were exposed, viz., weights coated to a nominal thickness of 13 or 25 μ of tin-nickel, and weights coated with 13 μ of tin-nickel over an undercoat of 13 μ of copper. Weights of 25-20 chromium-nickel steel and of 80-20 nickel-chromium alloy were included for comparison, also rhodium-plated weights representative of plated weights of normal production, and the tests were extended to include sheet-metal weights of 25-20 steel, aluminium, tantalum, titanium, and zirconium. Details of exposure conditions are given. The tests were made in three laboratories, and examination after exposure of one, two, and three months was carried out at the National Physical Laboratory. Some results of six-month exposures of tin-nickel-plated and 80-20 nickel-chromium alloy weights, provided by one of the co-operating laboratories, are also included in the report.

In the corrosive atmospheres of the three laboratories, the brass weights coated with tin-nickel alloy, in both thicknesses, and the weights carrying the composite

copper/tin-nickel alloy coating proved about equally resistant to change of mass: in this respect they were comparable with weights of 25-20 austenitic stainless steel and with platinum-, rhodium- or chromium-plated brass weights having the same minimum overall thickness of coating. As judged by appearance after exposure, the weights having a total 25 μ coating (whether tin-nickel only or copper/tin-nickel) showed better resistance than those on which 13 μ of tin-nickel alloy had been deposited direct. In the most severe conditions of test the 25 μ coating consisting solely of tin-nickel alloy showed the best behaviour. The alloy plating appears to be immune from 'fogging', and the tin-nickel alloy does not show any magnetic properties which would render it unsuitable for this type of application. Although in highly corrosive atmospheres weights of 80-20 nickel-chromium alloy have proved slightly less resistant to attack than those referred to above, this does not detract from their suitability for use under normal conditions.

Comparison of sheet-metal fractional weights showed the stainless steel to be outstandingly the best, followed, in descending order of merit, by zirconium, tantalum, and aluminium, and finally titanium.

Contact Corrosion of Stainless Steels in Water at Elevated Temperatures

H. A. PRAY and W. E. BERRY: 'Contact Corrosion of Stainless Steels in Water at Temperatures up to 600°F. (315°C.).' *U.S. Atomic Energy Commission Report BMI*-886, Nov. 24, 1953 (recently declassified); 24 pp.

This report describes tests made with crevice specimens, to determine liability to seizure during service in water at elevated temperatures. The specimens consisted of pairs of 1 in. × 3½ in. flat pieces of the materials to be tested, ground to a surface roughness of less than 63 microinches. The crevice itself was a 3-in. long groove or trough, ground to the desired depth across one of these pieces, leaving ¼-in. 'lands' at each end. The crevice assembly was completed by bolting the trough piece to a flat cover plate, through holes drilled ⅛ in. from both ends of each specimen. 18-8 chromium-nickel steel nuts and bolts were used in all the tests. Crevice clearances of 0·5, 1 and 5 mils were studied, and 'staircase' specimens carrying all three clearances on one specimen were also used. In addition, several journal-sleeve type specimens were tested: these were wired together, giving a crevice which varied from metal-to-metal contact on one side to twice the diametrical clearance on the other.

Straight-chromium steels (12 and 16 per cent. chromium), niobium-stabilized 18-8, and 17-4 chromium-nickel steels, variously combined in the test specimens, were exposed in (1) hot water containing oxygen (with or without lithium hydroxide), (2) hot water containing hydrogen, (3) hot degassed water. The samples were removed every two weeks for inspection, and fresh test solution was put into the vessels. Duration of test varied in the respective solutions, up to six months.

The results, reported in extenso, show that four factors affect corrosion and subsequent seizing of stainless-steel crevice specimens exposed to water at 600°F. (315°C.):—

(1) *The composition of the steel:* the steel containing 12 per cent. of chromium was the least resistant, and the 17-4 chromium-nickel type the most resistant.

(2) *The geometry of the crevice:* journal-sleeve type specimens seized more readily than those of plate type.

(3) *Duration of exposure to high-temperature water:* seizure was more severe and occurred on more couples after 8 weeks' exposure than after only 2 weeks in water of high oxygen content.

(4) *The amount of dissolved oxygen in the water.* The only seizure observed on plate-type specimens occurred on those exposed to water of high oxygen content. Since hydrogen-containing water did not promote formation of Fe_2O_3 (the presence of which appears to be essential for occurrence of seizing), it may be possible to overcome the adverse effects of oxygen by addition of hydrogen. Lithium-hydroxide additions also retarded seizing.

It is believed that seizing is more apt to occur on samples having small crevice clearances (up to 1 mil.), but this presumption is not yet fully substantiated.

Materials for Use in Production of Phosphoric Acid

J. J. PORTER and G. C. LOWRISON: 'Corrosion Problems in Phosphoric Acid Manufacture.' *Industrial Chemist*, 1954, vol. 30, Aug., pp. 369-72.

This paper, presented at a recent technical meeting of the International Superphosphate Manufacturers' Association, is based mainly on experience in the plant of one of the most important producers of agricultural fertilizers and related materials.

Wet-process phosphoric acid is made from sulphuric acid and phosphate rock; it thus contains, in addition to phosphoric, sulphuric, hydrofluosilicic and hydrofluoric acids, traces of hydrochloric acid, abrasive silica, and gypsum, also metallic salts such as sodium silicofluoride and calcium sulphate. The authors review the essential features of the three stages involved in the wet process (reaction, filtration, and evaporation), and give the composition of the media handled at each stage.

In their opinion, no materials, with the exception of high-molybdenum nickel-chromium-base alloys, are satisfactorily resistant to all the conditions involved, although it has been reported that high-alloy austenitic nickel-chromium steels containing molybdenum, copper and silicon give good resistance, and that aluminium bronzes are also useful. An alloy which the authors have found particularly satisfactory in service contains nickel 56, chromium 15, molybdenum 17, tungsten 5, iron 5, manganese 0·75, silicon 0·75, per cent. The 3-4 per cent. molybdenum stainless steels are strongly recommended, in preference to those of lower molybdenum content, and the importance of low carbon content is emphasized. Wrought material is generally to be preferred to castings, and in the U.S.A. the extra-low-carbon grades have been found specially suitable.

Lead gives good service in handling hydrofluosilicic acid up to 38 per cent. strength, but beyond this concentration it cannot be recommended. Lead castings containing about 6 per cent. of antimony, for evaporator bodies, have shown satisfactory life and reasonable mechanical strength, but this material is unsuitable for direct contact with mobile gypsum slurry, due to rapid erosion.

Some non-metallic materials may also be used in equipment for certain stages of the wet process: in this connexion the applications of mineral substances (graphite, cements, etc.), wood and rubber, and synthetic resins are discussed.

In the light of the information given on resistance of the various materials to attack under the conditions prevailing in the respective stages, a survey is made of the types used for individual items of the plant. In this section a chart is reproduced demonstrating the value of the high-molybdenum nickel-chromium alloy referred to on p.19, as exemplified by corrosion loss-in-weight data on impellers.

In closing, the authors reiterate the warning that 'the only reliable method of deciding on a material of construction is to try it out. . . . Laboratory tests are only a guide and can never give positive results.'

Corrosion-Resisting Nickel-containing Materials in the Petroleum Industry

HENRY WIGGIN AND CO., LTD.: 'Corrosion in the Petroleum Industry.' *Publn.* 722*, 1954; 35 pp.

The high capital investment involved in erection and operation of plant in the petroleum industries necessitates particularly careful consideration of materials of construction, in order to avoid shutdown for periods other than those required for routine overhaul and maintenance. Among the factors vital in this connexion are materials and design which will ensure a minimum of deterioration by corrosion and erosion.

The authors of this publication review the processes currently used in the various branches of the industry: distillation, cracking, refining, and the various methods for the manufacture of high-octane petrol, e.g., polymerization, alkylation, and isomerization. The operations involved, the media handled, and the nature of the equipment used, are described, with illustrations of typical plant, and a chart shows the flow sheet for production of aviation spirit, from the crude through to the finished product. Special consideration is given to the nature and degree of the corrosion attack to which materials of construction are exposed in the various processes: the use which has been made of selected types of corrosion-resisting material is demonstrated by information based on industrial experience culled from a number of contributors. As would be expected, the nickel-chromium stainless steels (particularly the molybdenum-containing grades), Monel, nickel-molybdenum-base alloys, and other nickel-containing alloys play an important part in prevention of the heavily corrosive attack to which unalloyed steel and many other metallic materials would be subject in the conditions involved.

* *We shall be pleased to supply a free copy of this publication.*

Resistance of Stainless Steels and Nickel-Molybdenum-base Alloys to Iodine

J. GURLAND: 'A Note on Corrosion-Resistance of Certain Alloys to Iodine Tincture, U.S.P.' *Jnl. Amer. Pharmaceutical Assocn.*, 1954, vol. 43, July, p. 444.

In order to determine the most suitable materials for use as iodine containers, corrosion tests were made (under the sponsorship of the Chilean Iodine Educational Bureau, at Battelle Memorial Institute) on Hastelloy alloys A, B and C (nickel-molybdenum base), on Stellite No. 6 (cobalt-chromium base) and on three grades of austenitic stainless steel:— straight 18-8 chromium-nickel, 16-13 chromium-nickel containing 3 per cent. of molybdenum, and 18-14 chromium-nickel containing 3·5 per cent. of molybdenum.

The tincture used (U.S.P. XIV) was of the following composition: iodine 20 g., sodium iodide 24 g., dilute alcohol (49·5 per cent. by volume) in amount sufficient to make 1,000 c.c. The test was made under static-immersion conditions, and rate of attack was calculated from loss in weight. Two specimens of each material, each having an average surface area of approximately 4 sq. in., were polished and sealed into glass ampoules containing 130 ml. of the iodine solution. The ampoules were then kept at 104° ± 0·2°F. for 32 days in an oil bath.

Corrosion rates (calculated as in./yr. and m.d.d.) are tabulated for each material tested. Only Hastelloys A and B (containing nickel, molybdenum and iron, but no chromium) showed a corrosion scale: this could be easily removed with soap and water, leaving a strongly etched surface. The straight 18-8 chromium-nickel steel showed the lowest loss (average 0·000003 in./yr.; 0·02 m.d.d.), and it is observed that although the data are considered to be too limited to permit generalization, it is significant that all the materials containing chromium had much lower rates of corrosion than the two (Hastelloy A and B) from which that element was absent.

Stainless-Steel Railway Coaches

'Pullman-Standard Designs Stainless-Steel Passenger Coach.' *Railway Locomotives and Cars*, 1954, vol. 7, July, pp. 39-41.

Stainless steel has recently been used by Pullman-Standard Car Manufacturing Company as the principal structural material for railway passenger coaches for the Missouri-Kansas-Texas Railroad. The Company first used stainless steel as an exterior sheathing for railway coaches in 1936, but in the 72-passenger coach recently built it has been used much more extensively, e.g., for underframe, side frames, and roof. Certain parts of the underframe are of low-alloy steel. The stainless steel considered most suitable for such application is the 17-7 chromium-nickel high-tensile type, which has a yield strength of 60,000-80,000 p.s.i. (27-35·5 tons per sq. in.). Design of the coaches is illustrated by photographs and line drawings, and methods of welding used for the various parts are discussed.

Stainless Steel in Architecture

'Stainless Steel Roofing in the Foundry.' *Materials and Methods*, 1954, vol. 40, Oct., p. 116.

Galvanized corrugated roofing in the building which houses the pig-casting machine in the plant of Armco Steel Corporation required replacement every three or four years, due to accelerated corrosion caused by the lime wash used to prevent sticking of the hot iron to the moulds. Stainless-steel roofing, now in use, is still in good condition after seven years, during which no maintenance has been needed.

Determination of Tungsten in Steels

See abstract on p. 5.

Age-Hardenable Steels and Alloys: Reference Data

See abstract on p. 2.

PATENTS

Chemical Polishing of Nickel

A bath for use in chemically polishing nickel surfaces consists of 60–70 per cent. by volume of glacial acetic acid, 40–30 per cent. by volume of concentrated nitric acid, and about 0·5 c.c. of concentrated hydrochloric acid, per 100 cc. of solution.

L. P. FOX, assignor to RADIO CORPN. OF AMERICA. *U.S. Pat.* 2,680,678.

Production of Metal Powders by Reduction of Metal Compounds

Metal powders, e.g., iron, cobalt, chromium, cadmium, zinc, nickel, molybdenum, tin, are made by reducing a compound of the metal with an alkali metal addition product of an ether of a polyhydric alcohol, e.g., the sodium adduct of ethylene glycol dimethyl ether. The metal compound and the alkali metal are preferably both dissolved in the ether and the reaction is carried out in an inert atmosphere.

ETHYL CORPN. *Brit. Pat.* 719,835.

Production of Metal Powders by Water Disintegration

Powders of metals and alloys, e.g., of iron, stainless steel, nickel-chromium alloys, lead-copper alloys, or nickel-copper alloys, are made by pouring a stream of molten metal through an annular, conical jet of water, in a non-oxidizing atmosphere, at a pressure high enough to counteract the tendency for the water jet to suck air into the system.

F. W. BERK AND CO., LTD. (inventor, S. W. BEECHAM). *Brit. Pat.* 719,047.

Nickel-Sponge Cathodes for Thermionic Valves

A thermionic valve cathode is made by sintering a mixture of nickel powder (preferably as flat flakes of 100-200 mesh size) with a binder, e.g., stearic acid, in the form of a collar round a metal support.

J. G. BUCK, assignor to U.S. SECRETARY OF THE NAVY. *U.S. Pat.* 2,677,873.

Porous Nickel Plates

A nickel plate having more than 80 per cent. porosity is made by sintering successive layers of B-nickel powder on a support having a rough upper surface.

H. W. G. HIGNETT, assignor to INTERNATIONAL NICKEL CO., INC. *U.S. Pat.* 2,689,178.

Electrodes for Nickel-Alkaline Accumulators

Electrodes for accumulators are made by introducing electrochemically resistant non-porous metals or alloys into the pores of a porous, non-metallic shaped body, and subsequently impregnating this body with active material. The metal may be introduced, for example, by gas plating by decomposition of nickel carbonyl, or by impregnating with a nickel salt, e.g., precipitating hydrated nickel oxide with potassium hydroxide and reducing in hydrogen.

BADISCHE ANILIN- UND SODA-FABRIK, A.G. *Brit. Pat.* 719,013.

Addition of Nickel Compounds to Fuel Oils

The corrosive effects of vanadium-containing fuel oils are reduced by adding to them an oil-soluble compound of nickel, aluminium, or iron which, under combustion conditions, will react with vanadium pentoxide to form the corresponding metavanadate.

STANDARD OIL DEVELOPMENT CO. *Brit. Pat.* 719,069.

Undercoats for Nickel-Plated Parts

Iron and non-ferrous metals, including zinc, are rapidly nickel-plated by the steps of (*a*) copper or zinc plating; (*b*) highly polishing; (*c*) covering with a thin deposit of brass; (*d*) nickel plating for less than 1 minute, preferably 30 seconds. A preferred bath composition is given.

E. FREIENSTEIN. *Brit. Pat.* 717,985.

Electrodeposition of Tungsten-Nickel Alloys

An improved process for electrodeposition of alloys of tungsten with iron, cobalt, and nickel or other metals consists in using a plating bath of normal type to which is added 5–30 g./L. of silico-tungstic acid $H_8[Si\ (W_2O_7)_6]$. The anode may be the alloying metal, tungsten, or lead.

G. K. N. GROUP SERVICES, LTD. (inventors, R. ST. J. EMERY AND M. ODGERS). *Brit. Pat.* 719,802.

Immersion Nickel Plating

A nonmetallic body is wetted with an aqueous solution of a palladium salt, palladium is deposited by reduction, and nickel is then deposited on the prepared surface by immersing it in an aqueous bath containing a nickel salt and a hypophosphite.

W. J. CREHAN, assignor to GENERAL AMERICAN TRANSPORTATION CORPN. *U.S. Pat.* 2,690, 402.

Non-conductive and non-catalytic surfaces, such as plastics, hard rubber, wood, and ceramics, can be plated with nickel by immersion in a solution containing nickel ions and a hypophosphite by first incorporating in and exposing on the surface minute particles of

one of the elements iron, cobalt, nickel, aluminium, copper, silver, gold, palladium, or platinum, to act as growth nuclei.

G. GUTZEIT, W.J. CREHAN and A. KRIEF, assignors to GENERAL AMERICAN TRANSPORTATION CORPN. *U.S. Pat.* 2,690,401. (Similar to *Belgian Pat.* 522,181)

Foils and Coatings Produced by Thermal Decomposition of Metal Carbonyls

Metal foil is made by continuously depositing, on the surface of a revolving cylindrical roll heated to 350°-450°F. (177°-232°C.), metal obtained by thermal decomposition of a mixture of inert gas and metal carbonyl or metal hydride. The metal film is continuously stripped from the roll. The method is applicable to production of films of nickel, iron, chromium, molybdenum and cobalt.

Coatings are produced by heating the metal which is to be plated, under reduced pressure (18-23 inches of mercury), to a temperature high enough to cause decomposition of a compound, e.g., the carbonyl, of the coating metal, which is then introduced into the container. Examples given are the coating of steel and cast iron with nickel, cobalt, chromium, iron, tungsten and molybdenum.

A metal article to be plated, e.g., with nickel, cobalt, tungsten, molybdenum or their alloys by decomposition of the appropriate carbonyls, is heated and made the cathode in a high-voltage electrical field in a container, and the carbonyl of the plating metal is led in through a tube containing radioactive material.

O. F. DAVIS and H. G. BELITZ. *U.S. Pat.* 2,685,121.
H. A. TOULMIN. *U.S. Pat.* 2,685,124.
H. NACK. *U.S. Pat.* 2,685,535.
all three patents assigned to COMMONWEALTH ENGINEERING CO.

Monel in Ball-Point Pens

In a refillable ball-point pen the ball seating is made from Monel or from a natural or artificial hard gem.

MABIE TODD AND CO., LTD. *Brit. Pat.* 717,668.

Acid-Resisting Copper-base Alloy

An alloy claimed to be resistant to corrosion by hydrochloric and sulphuric acids contains aluminium 9·5-9·9, nickel 1·7-2·4, iron trace- 1·0, per cent., copper balance. The alloy is preferably quenched from 600°-650°C.

IMPERIAL CHEMICAL INDUSTRIES OF AUSTRALIA AND NEW ZEALAND, LTD. *Brit. Pat.* 718,987.

Acid-Resisting Nickel-Iron-Molybdenum Alloy

An alloy resistant to corrosion by non-oxidizing acids, e.g., hydrochloric and sulphuric acids, contains iron 30-70, molybdenum 1-25, antimony 0·25-3, copper up to 5, per cent., remainder nickel and incidental impurities. The nickel content is specified as at least 26 per cent.

W. O. BINDER and C. R. BISHOP, assignors to UNION CARBIDE AND CARBON CORPN. *U.S. Pat.* 2,678,881.

Uranium-Nickel Alloy

Corrosion-resistance of uranium and uranium-base alloys is improved by addition of nickel, and uranium-nickel alloys of specified composition are particularly suitable for use in neutronic reactors. The alloy U_6Ni is specifically claimed.

M. E. CIESLICKI and B. J. NELSON, assignors to U.S. ATOMIC ENERGY COMMISSION. *U.S. Pat.* 2,692,823.

Boron Additions to Metal Powders for Sintering

In making alloys (particularly carbon-free alloys), by pressing and sintering metal powders, boron is added (in amount from 0·001 to 0·8 per cent. of the sintered body), to improve diffusion during sintering and favour grain growth. Alloys specially mentioned are iron-nickel, iron-cobalt, and iron-aluminium.

DEUTSCHE EDELSTAHLWERKE, A.G. *Brit. Pat.* 716,473.

Heat-Treatment of Magnetic Nickel-Copper-Iron Alloys

Alloys containing nickel 50-80, copper 1-45, chromium, molybdenum, or tungsten 0-10, per cent., iron balance (at least 10 per cent.) are annealed at 1150°-1300°C., and then tempered at 400°-600°C. Both treatments are preferably carried out in hydrogen. Tempering may be effected after cooling from the annealing temperature to room temperature, or there may be an intermediate heat-treatment at a temperature at least 100°C. above the optimum tempering temperature. Instead of tempering, the alloy may be slowly cooled through the 600°-400°C. range, preferably at 55°-65°C. per hour.

VACUUMSCHMELZE, A.G. *Brit. Pat.* 717,823.

Temperature-Compensating Alloys

A temperature-responsive compensator alloy for magnetic measuring instruments contains nickel 29·25-31·5, chromium 0·3-2·9, silicon not more than 0·5, manganese not more than 1 per cent., iron balance. Up to 3 per cent. of the nickel may be replaced by cobalt. Preferred composition: nickel 30-31, chromium 0·4-1·2, manganese 0·2-0·5, silicon 0·1-0·3, cobalt 0·1 max., per cent.

GENERAL MOTORS CORPN. *Brit. Pat.* 718,256.

Springs for Instruments and Horological Use

Instrument, watch and clock springs are made of alloys containing nickel 50-68, iron 10-25, chromium 10-15, molybdenum and/or tungsten 5-10, per cent., with varying small amounts of beryllium and titanium. 3 per cent. of manganese and/or silicon may also be present.

R. STRAUMANN. *Brit. Pat.* 720,122.

Complex Nickel-Alloy Steel for Low-Temperature Service

Wrought alloy steel showing improved impact strength at temperatures below 0°C. contains carbon 0·25, manganese up to 2, silicon up to 1, copper 0·25–1·25, nickel 0·5–5, chromium 0·25–3·25, aluminium 0·08–0·3, nitrogen 0·013–0·03, per cent., balance iron + incidental impurities.

PYRENE CO., LTD. *Brit. Pat.* 717,896.

Creep-Resisting Steel

An alloy steel characterized by high load-carrying ability at elevated temperatures contains carbon 0·28–0·35, manganese 0·75–1·5, silicon 0·30–0·80, chromium 18·0–21·0, nickel 8·0–11·0, molybdenum 1·0–2·0, tungsten 1·0–2·0, titanium 0·40–0·90, sulphur 0·40 max., phosphorus 0·20 max., per cent., balance iron except for incidental impurities.

C. T. EVANS, assignor to UNIVERSAL-CYCLOPS STEEL CORPN. *U.S. Pat.* 2,677,610.

Cast Creep-Resistant Alloy

A nickel-base alloy having, in the as-cast condition, a life-to-fracture of at least 221 hours at 24,250 p.s.i. (10·8 t.s.i.) at 1500°F. (815°C.), and elongation at least 2·28 per cent., consists essentially of carbon 0–0·25, manganese 0–1, silicon 0–1, chromium 13–17, molybdenum 4–6, titanium 1·5–3, aluminium 1–4, boron 0·01–0·5, iron 8–12, per cent., nickel balance.

S. R. CALLAWAY and F. J. WEBBERE, assignors to GENERAL MOTORS CORPN. *U.S. Pat.* 2,688,536.

Modified Nickel-Chromium Alloys

Nickel-chromium alloys of the 80–20 type are claimed to tolerate more than the usual 0·4–0·5 per cent. iron without loss of resistance to oxidation at high temperatures if they contain silicon 0·2–2, cobalt 0·02–0·25, aluminium 0·01–1, calcium 0·01–0·2, rare-earth metal trace – 0·5 per cent.

J. M. LOHR, assignor to DRIVER-HARRIS CO. *U.S. Pat.* 2,687,956.

Titanium Carbide-base Cermets with Heat-Resisting Alloy Binders

Materials having high mechanical strength and good resistance to heat and oxidation consist of a carbide-phase component containing as a main constituent titanium carbide, with or without one or more carbides of other metals of high melting point, bonded with pre-formed nickel-chromium or cobalt-chromium alloys having high resistance to heat and oxidation at temperatures close to their melting points. The carbide constituent forms 40 to less than 60 per cent. of the mass.

METRO-CUTANIT, LTD. *Brit. Pat.* 719,852.

See also *Brit. Pat.* 719,896, in which a binder alloy containing chromium 5–30, cobalt 4–25 per cent., nickel remainder (91–45 per cent.) is cited.

Electrical-Resistance Alloys

An improved electrical-resistance alloy consists of nickel about 35, chromium about 20, calcium 0·001–0·20, aluminium 0·01–1, rare-earth metal trace–0·50 per cent., iron balance. The 'useful life' of this alloy (in ASTM B76–39 test conditions) at 1950°F. (1065°C.) is about 400 hours.

J. M. LOHR, assignor to DRIVER-HARRIS CO. *U.S.Pat.* 2,687,954 (divided out of 2,581,420).

Age-Hardening Austenitic Steel

An austenitic steel which hardens after solution treating at 2200°F. (1205°C.) or below and ageing at 1300°F. (705°C.) for 15 hours contains carbon 0·3–1·5, phosphorus 0·15–1, manganese 0·5–15, nickel 3–25, (nickel + manganese 9–30 per cent.), chromium 15–30, silicon up to 3, molybdenum/tungsten up to 3, nitrogen up to 0·4, sulphur up to 0·3, per cent., iron balance.

R. SCHEMPP, P. PAYSON and J. G. CHOW, assignors to CRUCIBLE STEEL CO. OF AMERICA. *U.S. Pat.* 2,686,116.

Austenitic Steels Resistant to Intercrystalline Corrosion

Austenitic chromium-nickel steels resistant to intercrystalline corrosion contain carbon up to 0·3, chromium 5–30, nickel 30–5, molybdenum 3–6, boron 0·006–0·1, per cent., the remainder being iron with the usual impurities.

GEBR.BÖHLER AND CO. *Brit. Pat.* 716,822.

Surface Treatment of Stainless Steel to Improve Corrosion-Resistance

The resistance of stainless steel to corrosion is increased by treating it, at a temperature not below 100°C. and under superatmospheric pressure, with phosphoric acid or a phosphate, in the presence of nitric acid and of a substance which will react with the nitric acid to form a nitrogen oxide or mixture of nitrogen oxides.

AKTIEBOLAGET BOFORS. *Brit. Pat.* 719,909.

Steel for Spinning Pots in Artificial Textile Manufacture

A spinning pot for spinning cellulosic filaments by the viscose process is made of a steel resistant to blackening by hydrogen sulphide. A suitable composition is as follows:—carbon less than 0·07, chromium 20–30, nickel 20–30, molybdenum 0·50–3·0, per cent., iron balance, with or without copper 1·0–3·0 per cent. The carbon content may be increased to 0·20 per cent. if carbide formers such as titanium, tantalum, niobium are present in amounts sufficient to combine with all the carbon, but the total titanium + tantalum + niobium must not exceed 4 per cent.

DEUTSCHE EDELSTAHLWERKE, A. G. *Brit. Pat.* 716,276.

Stainless Steel for Cold-Working

A stainless steel suitable for cold-working, especially for heading or upsetting to bolts, etc., contains carbon up to 0·15, manganese up to 15, chromium 10–25, nickel 7–20, copper 1–6, with sulphur, phosphorus, and selenium up to 0·4 per cent., balance iron.

F. K. BLOOM, assignor to ARMCO STEEL CORPN. *U.S. Pat.* 2,687,955.

Stress-Relief by Electrolytic Removal of Surface Layers

In working stainless steels and other alloys containing a high percentage of chromium and/or nickel, stresses set up by pressing or other working operations (e.g., the formation of holes in flame tubes) are eliminated by electrolytically removing a thin layer of metal from the surface. Fracturing during further working is thus prevented or considerably reduced.

P. A. CHARLESWORTH. *Brit. Pat.* 716,487.

Heat-Treatment for Reduction of Gas Permeability

The permeability, to hydrogen, of stainless steel gas containers is reduced by heating the material from which they are made, before use, at 600°C. or above in hydrogen for 24 hours or longer.

T. R. P. GIBB, assignor to U. S. ATOMIC ENERGY COMMISSION. *U.S. Pat.* 2,685,546.

Production of Sulphide Coatings on Austenitic Steels

Sulphide coatings are formed on chromium-containing steels, particularly nickel-chromium steels, by treatment, at pH less than 6·5, with an aqueous solution containing (*a*) a sulphur compound which will provide sulphide ions at the metal surface, and (*b*) fluoride ions. The sulphur compound is preferably a sulphite.

PYRENE CO., LTD. *Brit. Pat.* 717,852.

Fusion Welding of Ferritic to Austenitic Steels

In making a fusion-welded joint between materials having different expansion coefficients, e.g., between ferritic and austenitic steels, a buffer layer or layers of one or more austenitic steels of intermediate thermal-expansion coefficients is interposed between them. Typical examples are given.

C. SYKES, H. W. KIRKBY and C. STOKES. *Brit. Pat.* 716,116.

Attention is drawn to the fact that many of the names of materials mentioned in The Nickel Bulletin are *Registered Trade Marks*.

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